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Final Report for AFOSR Grant 86-0274-A AFOSR-TR- 89-0411

This research has been concerned with two dimensional flows of an ideal fluid with concentrated regions of vorticity. The methods used involve ideas connected with conformal mapping and variational principles.

The previous work of the author and L.N. Trefethen on wakes bounded by constant pressure free streamlines in flows past polygonal obstacles was extended in two ways. The classical jet problem for flow from a polygonal nozzle was formulated so that a Schwarz - Christoffel type parameter problem could be solved to obtain the solution. This led to an efficient computational algorithm and a paper was published (F. Dias, A. Elcrat, and L. Trefethen, J. Fluid Mech. 185(1988) 275-288). The wake model was modified to include an underpressure near wake using the double spiral vortices of Tulin. Here the parameter problem arose in a natural way from the solution of a Riemann - Hilbert problem. This work led to an efficient algorithm for computing flows with a near wake and a far wake separated by the spiral vortices at which there is a jump in the free streamline speed. A paper was published (P. Bassanini and A. Elcrat ZAMP 39(1988) 455-467) in which this problem is analyzed and a criterion is given for determining the remaining disposable parameter using ideas from boundary layer theory.

Flows past three dimensional bluff bodies and lifting bodies were studied using the singular perturbation approach introduced by Van Dyke Perturbation Methods in Fluid Mechanics, 2nd edition, Parabolic Press (1975). The outer solution is a potential flow generated by a singularity distribution, and the inner solution is a two dimensional potential flow in which some parameters such as angle of attack and "downwash" have been reserved for specification by matching. We have used the double spiral vortex model described above for our inner solution. A manuscript has been written and accepted by the Journal of Engineering Mathematics. The computed results include flows past a GA(W) - 2 airfoil with a partial spoiler.

A computational algorithm for computing flows past an obstacle with a single vortex patch. This is a realization of the variational principle used in previous work (A. Elcrat and K. Miller, Comm. PDE 12(1987 1095-1115, B. Turkington, ibid. 8 (1983), 999-1030.) Extensive analysis was required in order to put the energy functional into a form amenable to computation. A manuscript has been written and will appear in Physica D.

A problem with a region of vorticity bounded by a vortex sheet has been studied during the last three months. This is the Riabouchinsky problem introduced by Pullin (Quart. J. Mech. Appl. Math 37(1984) 619-631). It is a prototype of the so-called Prandtl-Bachelor flows which does not have the technical complications due to a cusped wake closure. We have formulated a variational principle for this flow and begun computations. The relevant functional includes the "added mass" of an exterior obstacle consisting of the physical obstacle and vortex region, and the torsional rigidity of the vortex region. A single evaluation of the functional requires values of the Dirichlet integral

of the solutions of two Dirichlet problems, one interior, one interior. These are obtained by conformal mapping to the unit disk and using Fourier Series (FFT). First results are very promising.

In an another work, which is tangentiallv related to the research supported by this grant, a geometric problem for minimal surfaces was solved using Riemann Hilbert problems and the Gauss map. There is an analogy between this method and the solution of flow problems using the hodograph method. A paper has been accepted by the SIAM Journal on Mathematical Analysis.

The short term continuation of the work on this grant will include computation of a Sadovskii vortex using the methods described above, and further work on the singular perturbation problem using new outer solutions. In addition the free streamline problems with non polygonal cross section will be attacked.